THE REVISION KNEE: ISSUES THAT MATTER

The epidemiology of failure in total knee arthroplasty

AVOIDING YOUR NEXT REVISION

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Total knee arthroplasty (TKA) is a cost effective and extremely successful operation. As longevity increases, the demand for primary TKA will continue to rise. The success and survivorship of TKAs are dependent on the demographics of the patient, surgical technique and implant-related factors.

Currently the risk of failure of a TKA requiring revision surgery ten years post-operatively is 5%.

The most common indications for revision include aseptic loosening (29.8%), infection (14.8%), and pain (9.5%). Revision surgery poses considerable clinical burdens on patients and financial burdens on healthcare systems.

We present a current concepts review on the epidemiology of failed TKAs using data from worldwide National Joint Registries.

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PROMs are becoming popular in the assessment of satisfaction and health-gain post-operatively. Data from the Health and Social Care Information Centre (HSCIC) England show high post-operative PROM scores in the EQ-5D Index (82.1%), EQ-VAS (57.2%), and Oxford Knee Score (94.4%) for 2014 to 2015 following TKA, confirming the success of the operation.

NJRs provide a wealth of community-based comparative data including patient characteristics, implant factors, and surgical techniques. They highlight trends in the variation of outcomes whilst remaining sensitive to the impact of changing practice and allowing the identification of best practice. There is mounting recognition that registries are an excellent tool for improving the quality of care.
adjunct to randomised controlled trials in determining the safety and effectiveness of different interventions in a timely and cost effective manner.21-23 The Swedish Knee replacement project was established in 1975 and was the first NJR of its kind.24,25 With surgical advancement, the focus of the registry shifted from evaluating short-term complications of TKA to time to first revision. There are currently 11 NJRs worldwide which all use time to first revision as the primary endpoint.20 Presently, no other benchmark exists for the assessment of clinical outcome. Furthermore, monitoring revision rates permits the identification of factors influencing the outcome.

**Indications for revision**

More than 76 000 TKAs are performed annually in the United Kingdom and risk of revision following primary TKA for osteoarthritis (OA) ten years post-operatively is < 5%.26 This figure is consistent across a number of registries including 4% in Sweden, 5% in New Zealand, and 6.8% in Australia.26-30 Pooled data from registries worldwide identifies that the most common indication for revision surgery is aseptic loosening (29.8%), followed by infection (14.8%) and pain (9.5%) (Table I).31-34 Infection and pain as indications for revision have increased compared with aseptic loosening which has fallen since the NJRs first began (Fig. 1).27 The American Joint Replacement Registry (AJRR) highlights the fact that 68% of patients who underwent revision TKA between 2012 and 2013 did so within three months of the initial procedure.30 Patellofemoral pain, instability, and stiffness comprise the other main indications for revision surgery.

Large non-registry cohort studies echo similar findings with aseptic loosening and infection being the most common indication for revision TKA (Table II).35-46 Studies published from 2010 onwards clearly demonstrate that infection is the most common indication for revision within two years of the primary procedure, and aseptic loosening is the most common indication for late revision.36,38,40-43 This trend has also been observed in NJRs.26-30 Polyethylene wear and its sequelae of osteolysis and late instability are now uncommon. However, this was the dominant indication for revision in studies published prior to 2006, accounting for almost 25% of all revisions (Table II).35,44-47 Advancement in surgical techniques, tribology and polyethylene manufacturing (gamma sterilisation in inert environments and the use of highly cross-linked polyethylene) may have contributed to fewer polyethylene- and implant-related failures.37 Fehring et al46 concluded that the total number of early revision TKAs and the overall rate of revision could be reduced by 40% and 25%, respectively, if all TKAs were routinely cemented with careful balancing of the ligaments.

Pain, instability, and stiffness are more likely to be reported now as causes of failure after TKA in NJRs26-29 and retrospective studies undertaken in the US36,37,40,41 in contrast to multicentre studies from Korea and Japan.38,39 This observation may be partially explained by the fact that European NJRs and data series from the United States would include operations on a much younger cohort of patients.

### Table I. Variation trends for the indication of revision TKA for the most commonly referred to National Joint Registries (NJR)

<table>
<thead>
<tr>
<th>NJR England, Wales, and Northern Ireland</th>
<th>Swedish knee arthroplasty register</th>
<th>Australian orthopaedic association NJR</th>
<th>New Zealand NJR</th>
<th>American NJR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st annual report 200422 (%)</td>
<td>11th annual report 201426 (%)</td>
<td>1st annual report 199923 (%)</td>
<td>1st annual report 200024 (%)</td>
<td>14th annual report 2014 (%)</td>
</tr>
<tr>
<td>Aseptic loosening</td>
<td>Deep infection</td>
<td>Pain</td>
<td>Irish Orthopaedic Society</td>
<td>Pain</td>
</tr>
<tr>
<td>41.4</td>
<td>18.4</td>
<td>23.0</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>32.0</td>
<td>22.0</td>
<td>15.0</td>
<td>0</td>
<td>2.6</td>
</tr>
<tr>
<td>43.6</td>
<td>11.2</td>
<td>n/a</td>
<td>32.7</td>
<td>9.6</td>
</tr>
<tr>
<td>26.0</td>
<td>22.0</td>
<td>n/a</td>
<td>0</td>
<td>174</td>
</tr>
<tr>
<td>40.3</td>
<td>9.1</td>
<td>2.6</td>
<td>34.6</td>
<td>274</td>
</tr>
<tr>
<td>32.7</td>
<td>174</td>
<td>9.6</td>
<td>N/a</td>
<td>45.7</td>
</tr>
</tbody>
</table>

TKA, total knee arthroplasty

**Fig. 1**

Graph showing the cumulative incidence of the indication for revision of primary total knee arthroplasty. (Reproduced from Australian Orthopaedic Association NJR: Annual Report 2014).
patients. Such patients are more physically active with higher demands and expectations, therefore placing greater strain through the prostheses leading to earlier failure. Operating on younger patients highlights the importance of meticulous ligament balancing.

The risk factors for revision surgery

Patient factors. The age and gender of the patient are major factors affecting the outcome of primary TKA. All registries concur that the rate of revision increases with decreasing age.26-29,48 In Sweden, patients aged < 65 years have twice the risk of revision compared with those aged > 75 years, regardless of diagnosis or the type of implant.29 In Australia, four years post-operatively, patients with osteoarthritis aged < 55 years have > 4.5 times the risk of revision than do those aged > 75 years.27 Men have higher rates of revision than women (Fig. 2).26-29,38 In England, Wales, and Northern Ireland, the Cumulative Risk of Revision (CRR) in men aged > 75 years is 2% ten years post-operatively, whereas in those aged < 55 years it is 12%.26 A large multicentre study reported similar findings: for every ten years of increasing age, the overall risk of failure of TKA decreased by 60% (OR 0.41; 95% confidence interval (CI) 0.37 to 0.49).38 It is therefore imperative that younger patients are fully informed of the increased risk of revision by referencing registry data, especially as the demand for TKA in younger patients rises (Fig. 3). The reasons for this demand include higher patient expectations and an increased incidence of degenerative joint disease resulting from the obesity pandemic.49,50

Table II. Indications for revision surgery over the last decade from retrospective cohort studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Study Design</th>
<th>No. of revision TKAs</th>
<th>Male / female (No. of patients)</th>
<th>Mean age at RKA (yrs)</th>
<th>Years of operations</th>
<th>Mean follow-up time</th>
<th>Mean time to revision</th>
<th>Ratio of early*/late† revision</th>
<th>Causes of revision knee procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharkey et al, 201425</td>
<td>Single centre RR</td>
<td>781</td>
<td>291 / 453</td>
<td>Male: 65.4 (37 to 96); Female: 65.1 (34 to 96)</td>
<td>2003 to 2012</td>
<td>NA</td>
<td>0.84 (1 day to 1.89 yrs) 6.9† (2 to 30.36)</td>
<td>37.6% / 62.4%</td>
<td>Aseptic loosening 39.9%; Infection 27.4%; Instability 7%; Fracture 4.7%; Arthrofibrosis 4.5%; PE wear: 3.5%</td>
</tr>
<tr>
<td>Le et al, 201437</td>
<td>Single centre RR</td>
<td>253</td>
<td>103 / 143</td>
<td>64</td>
<td>2001 to 2011</td>
<td>N/a</td>
<td>35 mths (9 to 51)</td>
<td>46% / 54%</td>
<td>Infection 24%, 25% Instability 26%; PE wear 18%; 14% Arthrofibrosis 18%; 9%</td>
</tr>
<tr>
<td>Koh et al, 201428</td>
<td>Multi centre RR</td>
<td>634</td>
<td>NA</td>
<td>NA</td>
<td>2008 to 2012</td>
<td>5 yrs</td>
<td>76.5 mths (1 to 312)</td>
<td>27% / 73%</td>
<td>Infection 38% Aseptic Loosening 33% Wear 13% Instability 7% Arthrofibrosis 3%</td>
</tr>
<tr>
<td>Kasahara et al, 201329</td>
<td>Multi centre RR</td>
<td>140</td>
<td>27 / 113</td>
<td>72.9 (71.5 to 143)</td>
<td>2006 to 2011</td>
<td>36 months (12 to 132)</td>
<td>73 mths (2 to 420)</td>
<td>NA</td>
<td>Aseptic loosening 40%; Infection 24%; Wear 9%; Instability 9%; PE wear 6%; Fracture: 4%;</td>
</tr>
<tr>
<td>Dalury et al, 201330</td>
<td>Multi centre RR</td>
<td>820</td>
<td>283 / 410</td>
<td>69 (24 to 94)</td>
<td>2000 to 2011</td>
<td>NA</td>
<td>6 yrs (0.1 to 26)</td>
<td>49% / 51%</td>
<td>Aseptic loosening 23.1%; Infection 18.4%; PE wear 18.1%; Instability 17.7%; Pain/stiffness 9.3%; Arthrofibrosis 7%</td>
</tr>
<tr>
<td>Schroer et al, 201331</td>
<td>Single centre RR</td>
<td>844</td>
<td>313 / 531</td>
<td>65</td>
<td>2010 to 2011</td>
<td>NA</td>
<td>5.9 yrs (10 days to 31 yrs)</td>
<td>35.3% / 64.7%</td>
<td>Aseptic loosening 31.2%; Instability 18.7%; PE wear 10%; Arthrofibrosis 7%</td>
</tr>
<tr>
<td>Haasper et al32</td>
<td>Single centre RR</td>
<td>150</td>
<td>NA</td>
<td>NA</td>
<td>2009</td>
<td>NA</td>
<td>55 mths (0.5 to 125 mths)</td>
<td>NA</td>
<td>Aseptic loosening 30.7%; Instability 24.7%; Stiffness 17.3%; Component malposition 6%</td>
</tr>
<tr>
<td>Bozic et al, 201033</td>
<td>Nationwide Inpatient Sample RR</td>
<td>60 355</td>
<td>25 711 / 34 644</td>
<td>65.8</td>
<td>2005 to 2006</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>Infection 25.2%; Aseptic loosening 16.1%; Implant failure 9.7%</td>
</tr>
<tr>
<td>Hussain et al, 201334</td>
<td>Single centre RR</td>
<td>349</td>
<td>204 / 139</td>
<td>67.8 (32 to 94)</td>
<td>1999 to 2008</td>
<td>5.77 mths</td>
<td>84.3 mths (1 to 167)</td>
<td>32% / 68%</td>
<td>Infection 35.7%; Aseptic loosening 14.9%; PE wear 12.3%; Conversion from UKA 8.3%</td>
</tr>
<tr>
<td>Mulhall et al, 200635</td>
<td>Multi-centre PCS 318</td>
<td>318</td>
<td>NA</td>
<td>68.7 (34 to 85)</td>
<td>NA</td>
<td>1 yr</td>
<td>7.9 yrs (0.5 to 27 years)</td>
<td>69% / 31%</td>
<td>Osteolysis: 59.4% Aseptic loosening: 41.3%; Instability 28.9%; PE wear: 24.9%; Failed PE insert 18.1%; Infection 10.4%</td>
</tr>
<tr>
<td>Sheng et al 200436</td>
<td>MA on 33 studies &amp; 1366 patients</td>
<td>NA</td>
<td>429 / 611</td>
<td>67 (45 to 90)</td>
<td>1990 to 2002</td>
<td>57 mths (6 to 108)</td>
<td>N/A</td>
<td>N/A</td>
<td>Aseptic loosening 55%; PE wear 11%; Instability 10%; Disease progression 4%</td>
</tr>
<tr>
<td>Sharkey et al, 200237</td>
<td>Single centre RR</td>
<td>212</td>
<td>75 / 128</td>
<td>Male: 68.7 (31.6 to 88.7); Female: 68.4 (36.1 to 96.9)</td>
<td>1997 to 2000</td>
<td>NA</td>
<td>1.1* (9 days to 2 yrs) 55.6% / 42.4% (2.2 to 28)</td>
<td>PE wear: 25%; Aseptic loosening 24.1%; Instability 17.5%; Arthrofibrosis: 14.6%; Malposition: 11.8%</td>
<td></td>
</tr>
<tr>
<td>Fehring et al, 200138</td>
<td>Single centre RR</td>
<td>440</td>
<td>1356 patients</td>
<td>1986 to 1999</td>
<td>5 years</td>
<td>19 months</td>
<td>63% within 5 years of index procedure</td>
<td>N/A</td>
<td>Infection 38%; Instability 27%; Failure of ingrowth (cementless fixation) 13%; Patellofemoral problems 8%; PE wear 7%;</td>
</tr>
</tbody>
</table>

* Early revision (< 2 years post primary total knee arthroplasty)
† Late revision (> 2 years post primary total knee arthroplasty)
§ Defined early revision < 5 years post index procedure
RR, Retrospective review; PCS: prospective cohort study; MA: meta-analysis; NA: not available; US, United States, UK, United Kingdom
Patients with rheumatoid arthritis who undergo TKA have the highest rate of revision secondary to infection, especially in men.\textsuperscript{29,51,52} However, with improved medical management the number of rheumatoid patients requiring TKA has fallen dramatically.\textsuperscript{29}

**Surgical technique.** The year of primary operation affects the likelihood of revision. The cumulative percentage probability of a revision being undertaken increases slightly for each operative year between 2003 and 2007.\textsuperscript{26} Thus, the risk of revision five years post-operatively for patients who underwent TKA in 2008 was 3\% compared with 1.7\% for those whose operation was undertaken in 2003 (Fig. 4).\textsuperscript{26} This variation may reflect incomplete data in the NJR until about 2007/8. The Swedish Knee Arthroplasty Register (SKAR) has captured a large range of data over a much greater period and illustrates the reducing risk for revision over time (Fig. 5).

When considering all knee procedures, partial arthroplasties account for between 7\% and 9\%, primary TKAs for between 83\% and 88\%, and revision TKAs for between 5\% and 8\%.\textsuperscript{26-29} Partial arthroplasty including unicondylar, patellofemoral, bicompartamental, unispacer, and partial resurfacing, has a higher rate of revision than TKA.\textsuperscript{26-29} unicompartmental arthroplasty (UKA) comprises > 90\% of all partial procedures.\textsuperscript{26-28} Proponents of UKA cite as advantages the preservation of normal
kinematics, lower peri-operative morbidity, blood loss and risk of infection compared with TKA, and an accelerated rehabilitation and recovery. 53-55 However, the volume of UKAs which are undertaken has diminished over time and continues to decline (Fig. 6). 26,27,29 The Australian registry reports that the number of UKAs undertaken in 2013 had decreased by 2.7% compared with the previous year and by 49.5% compared with 2003. 27 One reason for this decline is that UKA performed for osteoarthritis has a substantially higher risk of revision 26,27,29 and for re-operation. 55 The rate of revision for UKA has been reported to be twice as high as the equivalent group of TKAs at each period of review post-operatively, and three times higher at ten years post-operatively. 26 The CRR for primary UKA ranges from 12.7% at ten years 26 to 19.1% at 13 years 27 post-operatively. One reason for the higher failure rates is offering UKA to younger patients. 26,29 This delays the need for a TKA in younger patients with mild disease but often such patients are more active and put a greater amount of strain on their implants. This explains the high CRR ten years post-operatively in patients aged < 55 years who undergo UKA (21%) compared with that of patients aged > 75 years who undergo UKA (6%). It has been estimated that if 100 patients undergoing TKA received a UKA instead this would result in one fewer death and three more re-operations during the first four post-operative years. 55

Finally, the risk of subsequent revision is twice as high in patients who have undergone conversion from a UKA to a TKA than for primary TKA. 29 Revision of a failed UKA to another UKA is rare and reflects the higher risk of re-revision associated with this than if the UKA is revised to a TKA. 27,29

Information from the New Zealand Joint Registry shows no difference in the rate of revision in relation to the operative approach (i.e. medial or lateral parapatellar approach). 28 This registry also showed that patients were statistically twice as likely to develop periprosthetic infection requiring revision surgery within six months of the initial procedure if it had been performed in a laminar flow theatre (revision risk (RR) 0.24%) rather than a conventional operating theatre (RR 0.11%). On further analysis, the rates of revision for deep infection within six months were 2.9 times higher if the operation was undertaken in a conventional theatre using space suits (RR 0.26%) and 2.8 times higher if it was undertaken in a laminar flow theatre using space suits (RR 0.25%), compared with operating in a conventional theatre without space suits (RR 0.09%). Furthermore, the rate of revision rate doubled with the use of spacesuits in either conventional or laminar flow theatres. 28 Such findings pose an interesting predicament and warrant further research and validation.

Historically, there has not been overwhelming evidence to support the use of bone cement or resurfacing of the patella during primary TKA; the choice lying with the surgeon. Data from NJRs show that the risk of revision is substantially increased with the use of uncemented compared with cemented implants. 26,29 They also confirm that > 80% of TKAs are performed with cement. Cox regression analysis, adjusting for age, gender, year of operation, and use of patellar component, showed that the risk of revision for TKA with an uncemented tibial component was 1.7 (1.4 to 1.9) times higher than for that if a cemented component was used. 29

Resurfacing the patella is extremely variably undertaken across countries and remains an area of controversy (Table III). 56,57 A patellar button was used in > 70% of TKA cases in Sweden during the 1980s, but its use fell to 2.3% in 2013 (Fig. 7). 29 TKA performed without patellar resurfacing in Sweden between 1991 and 2000, however, had a significantly higher rate of revision than those performed with patellar resurfacing (RR × 1.3, 95% CI 1.1 to 1.4). Conversely, TKA performed with patellar resurfacing between 1999 and 2008 had a higher risk of revision (RR × 1.2, 95% CI 1.1 to 1.4). In contrast, the Australian registry reports an increase in patellar resurfacing from 41% of all TKAs in 2005 to 56.8% in 2013. 27 Estimating the impact of patellar resurfacing on the risk of revision is extremely complex and cannot explain the variations in the findings worldwide. Furthermore, registry data cannot accurately interpret the impact of patellar resurfacing on the success of TKA, especially if a secondary operation was required to resurface the patella to manage subsequent patellofemoral symptoms.

Almost one quarter of TKAs undertaken in Australia are computer navigated. 27 At ten years post-operatively, there is no overall difference in CRR between navigated and non-navigated TKAs. However, navigated TKAs performed in patients aged < 65 years are less likely to require revision for loosening or osteolysis. 27 Finally, the outcome is better if the operation is undertaken by a surgeon who performs a high volume of operations. This has been reported several times. 58,59
Implant design. In Australia an unconstrained (cruciate retaining) prosthesis is most commonly used (79.2%) followed by a posterior stabilised (cruciate sacrificing) TKA (28%). This is similar in England where an unconstrained prosthesis is the most popular (65.6%) followed by a posterior stabilised TKA (22.8%). Overall, the most commonly used TKA in England is a cemented unconstrained fixed bearing design, comprising 55.9%. This design has the lowest rate of revision with a CRR ten years post-operatively of 3%. Posterior stabilised designs have the highest rates of revision. For cemented TKA, the mobile-bearing posterior stabilised prosthesis has a CRR ten years post-operatively of 5%; and for uncemented TKA, the fixed-bearing posterior stabilised prosthesis has a CRR at ten years post-operatively of 9%. In contrast, the AJRR's first annual report (2013) clearly shows that the most popular design of TKA is posterior stabilised (59.1%) followed by unconstrained (40.1%). The impact of this on revision has not been estimated, perhaps as the registry is in its infancy.

The Australian Registry showed that fixed tibial bearings had a lower rate of revision compared with rotating or slide-rotating mobile tibial bearings. There were no differences in the rates of revision between the modular fixed tibial component and the non-modular all-polyethylene tibial component. However, the all-polyethylene tibial components have higher rates of revision compared with the polyethylene moulded tibial components. A large single centre retrospective study recently reported that all-polyethylene tibial components had a significantly lower risk of revision compared with metal-backed modular implants, (hazard ratio, 0.3; 95% CI 0.2 to 0.5; p < 0.0001) and therefore were associated with a better outcome. The authors also reported that in metal-backed modular tibial designs, unconstrained TKA performed better than the posterior-stabilised TKA (p = 0.002), which is consistent with registry findings.

Bearing surfaces have an important but undetermined role in TKA. Prostheses using high cross-linked polyethylene (XLPE) have a lower rate of revision compared with those using non-cross-linked polyethylene. The Australian Registry has shown a cumulative incidence of loosening or lysis of 0.8%, ten years post-operatively, for TKA using XLPE and 1.7% for TKA using non-XLPE. The overall rate of XLPE in Australia, however, is much less than non-XLPE. In the United States, XLPE is used in 75% of TKAs and non-XLPE in 25%.

Implant model. Registry analysis of TKAs by brand has shown a risk of revision ten years post-operatively of < 5% with overlapping CIs indicating similar performances in terms of the risk of revision. In England, the highest rates of revision related to the Rotaglide + mobile knee TKA which had a revision rate of 7.14% at ten years, and the Preservation UKA which had a revision rate of 20.14% at ten years. Using Cox regression analysis and adjustments for differences in gender, age and year of operation, the SKAR also found that the Preservation UKA had the highest risk ratio for revision (RR 1.57, p = 0.04; 95% CI 1.02 to 2.40). The TKAs performed in Sweden with the highest risk of revision are the F/S MIII (RR 1.45, p < 0.01; 95% CI 1.21 to 1.74) and the PFC RP (RR 1.67, p < 0.01; 95% CI 1.27 to 2.19). The New Zealand Registry report that the Innsall/Burstein (1.8 per 100 observed component-years; ocys) and Optetrak (0.93 ocys) prostheses have a significantly higher rate of revision than the overall rate of 0.5 per 100 ocys at the 95% CI. The Australian Registry reports that the Nexgen CR/Nexgen TKA has the overall lowest CRR ten years post-operatively of 3.2% (2.9% if uncemented and 2.7% if cemented). Using a standardised approach, they identified six types of TKA as outliers with respect to CRR. These include the Genesis II CR (cementless) / Profix Mobile (cemented) combination (ten year CRR, 13%); Genesis II Oxinium PS (cemented) / Genesis II (Cementless) combination (five year CRR, 31%); GMK Primary (cementless) / GMK Primary (Cementless) combination (one year CRR, 3%); Optetrak...
CR (cemented) / Optetrak (cemented) combination (ten year CRR, 11.9%); Scorpio NRG PS (cementless) / series 7000 (cementless) combination (five year CRR, 8.4%); Vanguard PS / Maxim combination (five year CRR, 5.8%); and the LCS PS femoral component (three year CRR, 7.5%). The comparator group includes all other types within the same class, regardless of their rate of revision.

In conclusion, registries are an indispensable tool in providing comparative data from large populations on the outcomes of individual TKAs in a community. Such data are critical to an evidence-based approach to the choice of prosthesis. Registries also serve as a system of quality-assurance surveillance to monitor the outcomes of new devices, generate observational evidence, and cost savings. However, there remains an important role for well-conducted large-scale randomised controlled trials to assess individual types of prostheses to a depth which cannot be achieved by registries. This will also minimise the introduction of new technologies directly from industry into health care. The National Institute for Health and Clinical Excellence (NICE) in the United Kingdom has set the benchmark for approving new prostheses at 10% revision ten years post-operatively.

The overall percentage of patients requiring revision TKA is low. However, with the large number of TKAs performed annually, this translates into a significant absolute number with considerable financial and healthcare implications for patients and healthcare systems. The survivorship of TKAs is determined by the changing demographics of patients, surgical technique and implant-related factors. The most common modes of failure include aseptic loosening, infection, pain and instability. Future research, education, and training should consider regenerative techniques that halt or reverse degenerative joint disease in younger patients, improving the selection of patients for surgery and the appropriate early evaluation and long-term monitoring of outcomes through prospective studies and NJRs.

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G. Green: Writing paper.
F. S. Haddad: Writing paper.

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References


